SNLS: Verifying the use of SNe Ia as cosmological probes

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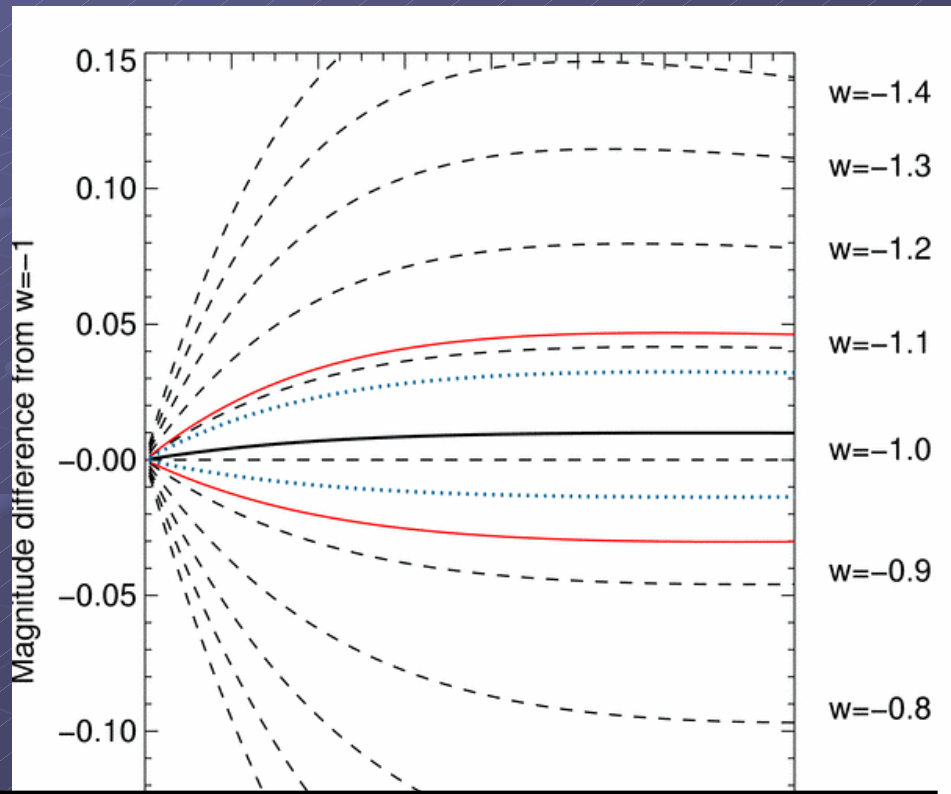
Where are we now?

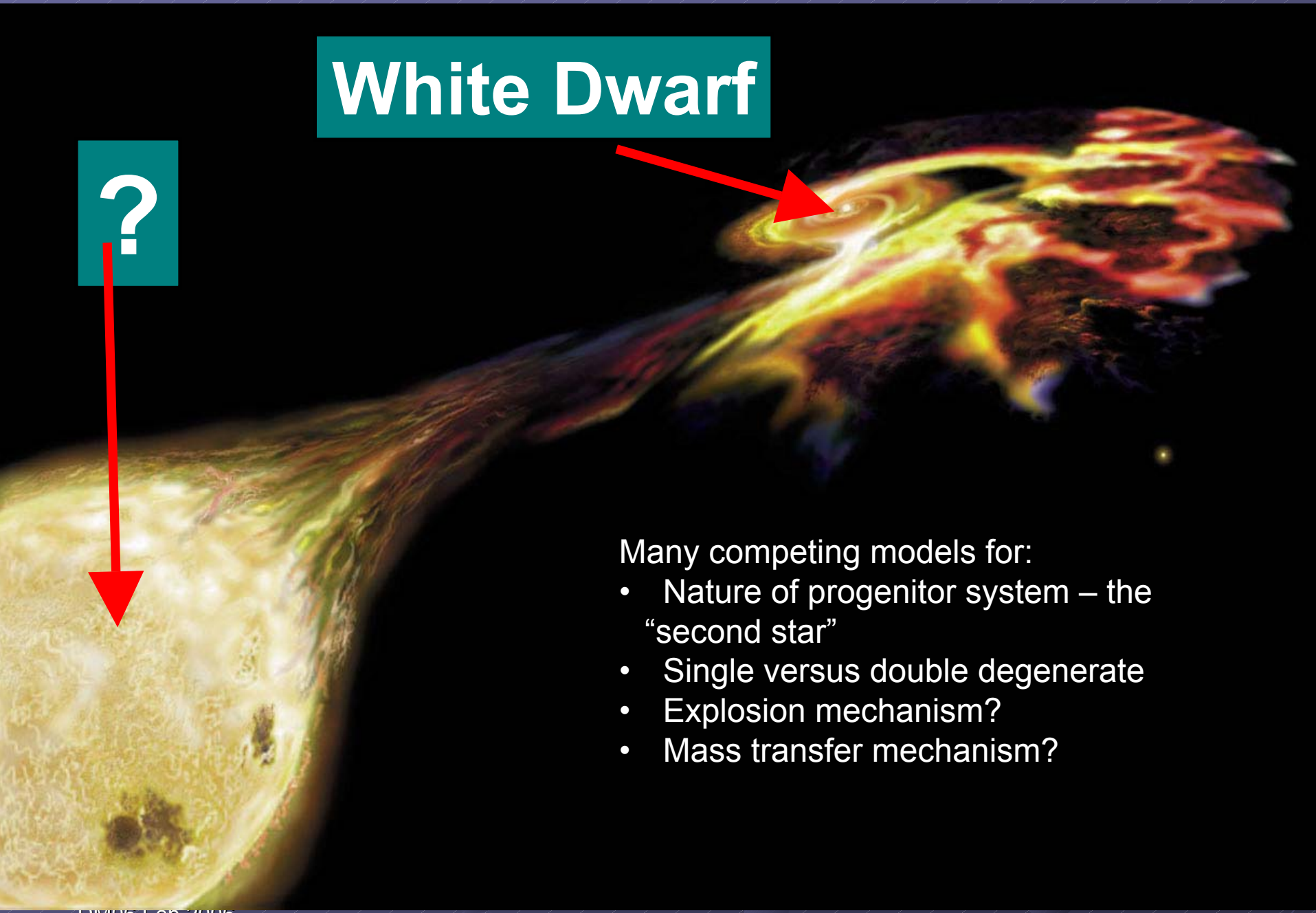
- SNLS: N~70; w=-1.02
- Current w errors:
  - ±0.09 (stat) (RED)
  - ±0.055 (sys) (BLUE)
- End-of-survey:
  - N~500-700
  - ±~0.05 (stat)
  - **±??? (sys)**



Substantial effort needs to be invested not only in “N”, but in reducing systematics – both observational (e.g. zeropoints) and those related to the SNe (e.g. population drift or “evolution”)

Understanding SNe Ia

- SNe Ia are only empirically understood. A theoretical understanding remains elusive.



Many competing models for:

- Nature of progenitor system – the "second star"
- Single versus double degenerate
- Explosion mechanism?
- Mass transfer mechanism?

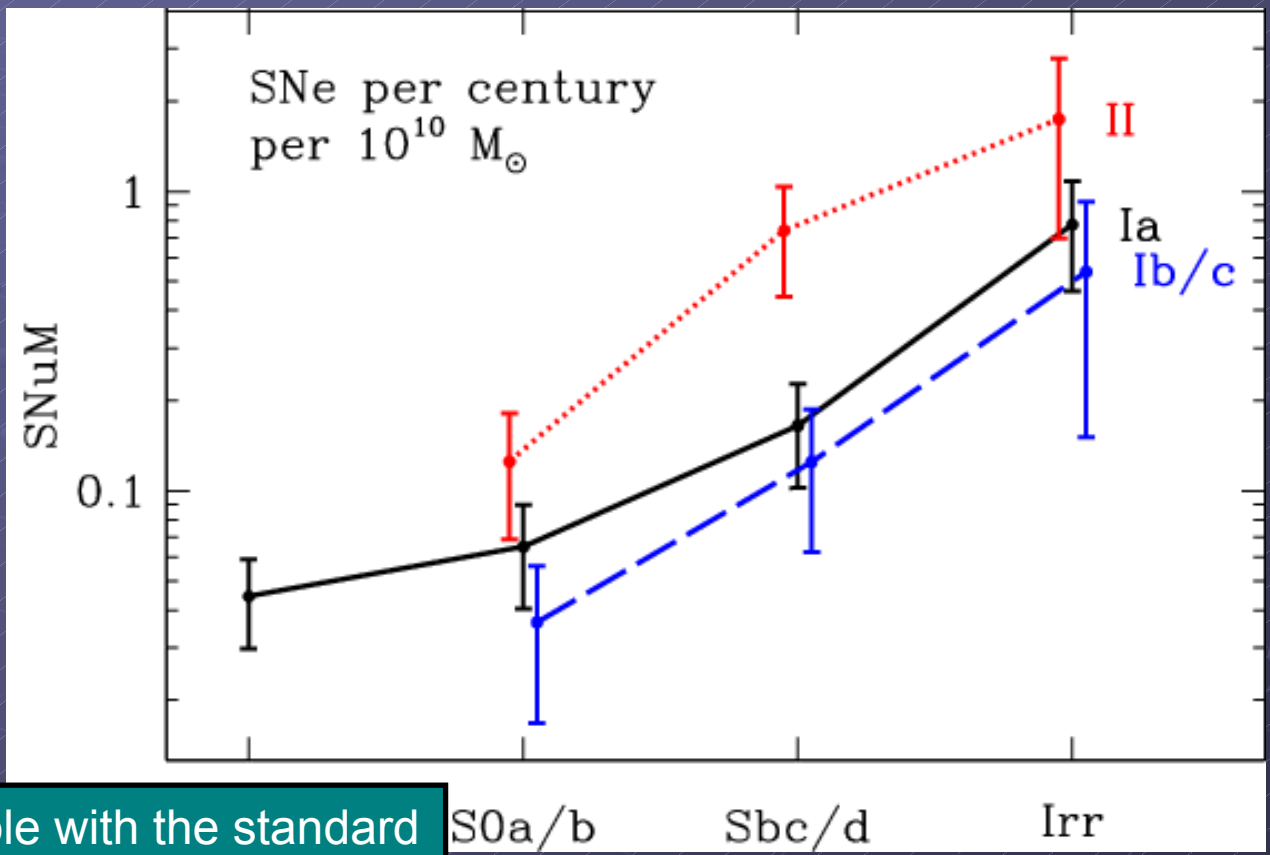
SNLS work on understanding SNe

- Relationship with environment (Sullivan et al)
  - SN explode in galaxies with different ages/metallicities
  - Population “drift”? – galaxy mix evolves with redshift
- Other programs:
  - High signal/noise UV spectroscopy (Ellis/Sullivan et al)
    - Progenitor metallicity mostly affects the UV
    - Evolution? Correlations with SN environment?
  - Rest-frame I-band Hubble diagrams (Freedman et al)
  - Alternative probes of expansion (SN IIP; Nugent et al)

The SNIa rate per unit mass

Mannucci et al. (2005)

SN Ia rate increases by a factor of ~20 from E/S0 to Irr galaxies



Seems incompatible with the standard assumption that SNe Ia originate from old progenitors!

The SNIa Rate

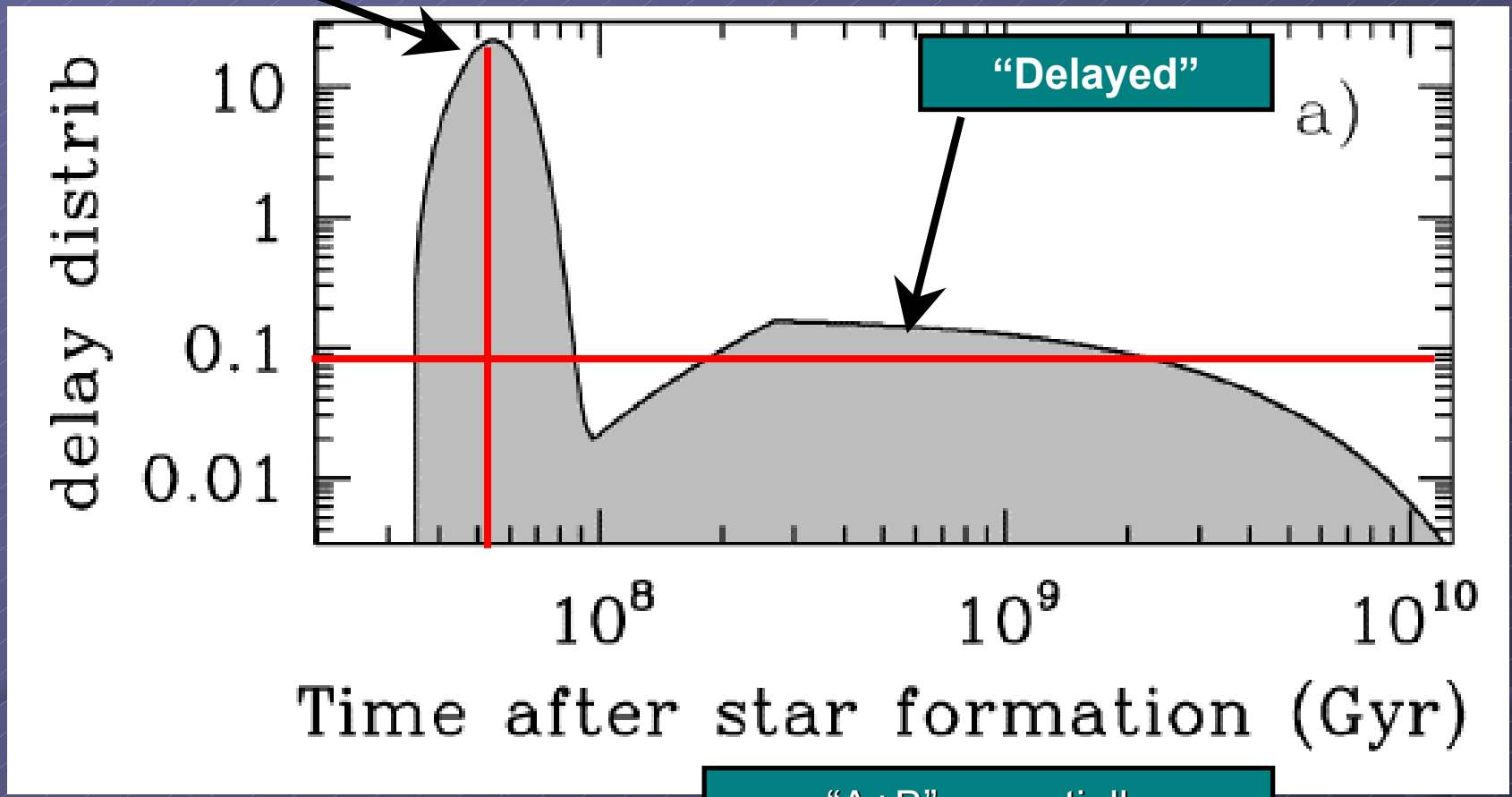
- General form for the probability of a SN Ia explosion:

$$\mathrm{SNR}_{\mathrm{Ia}}(t) = \int_0^t \dot{M}_{\mathrm{new}}(t')P(t-t')dt'$$

- P(t) contains all the (unknown!) physics for SNe Ia

- Scannapieco & Bildsten (2005): Two component model
  - *Prompt*: P=B @ t=0 and P=0 at all other times
  - *Delayed*: P=A constant with time

Mannucci et al. 2006 – P(t)



"A+B" essentially approximates the details of the SNIa delay-time probability distribution

“A+B” Model

$$\mathrm{SNR}_{\mathrm{Ia}}(t) = A\int_0^t \dot{M}_{\mathrm{new}}(t)\mathrm{d}t + B\dot{M}_{\mathrm{new}}(t)$$

$$\mathrm{SNR}_{\mathrm{Ia}}(t) = A.M_{\mathrm{stellar}} + B.SFR$$

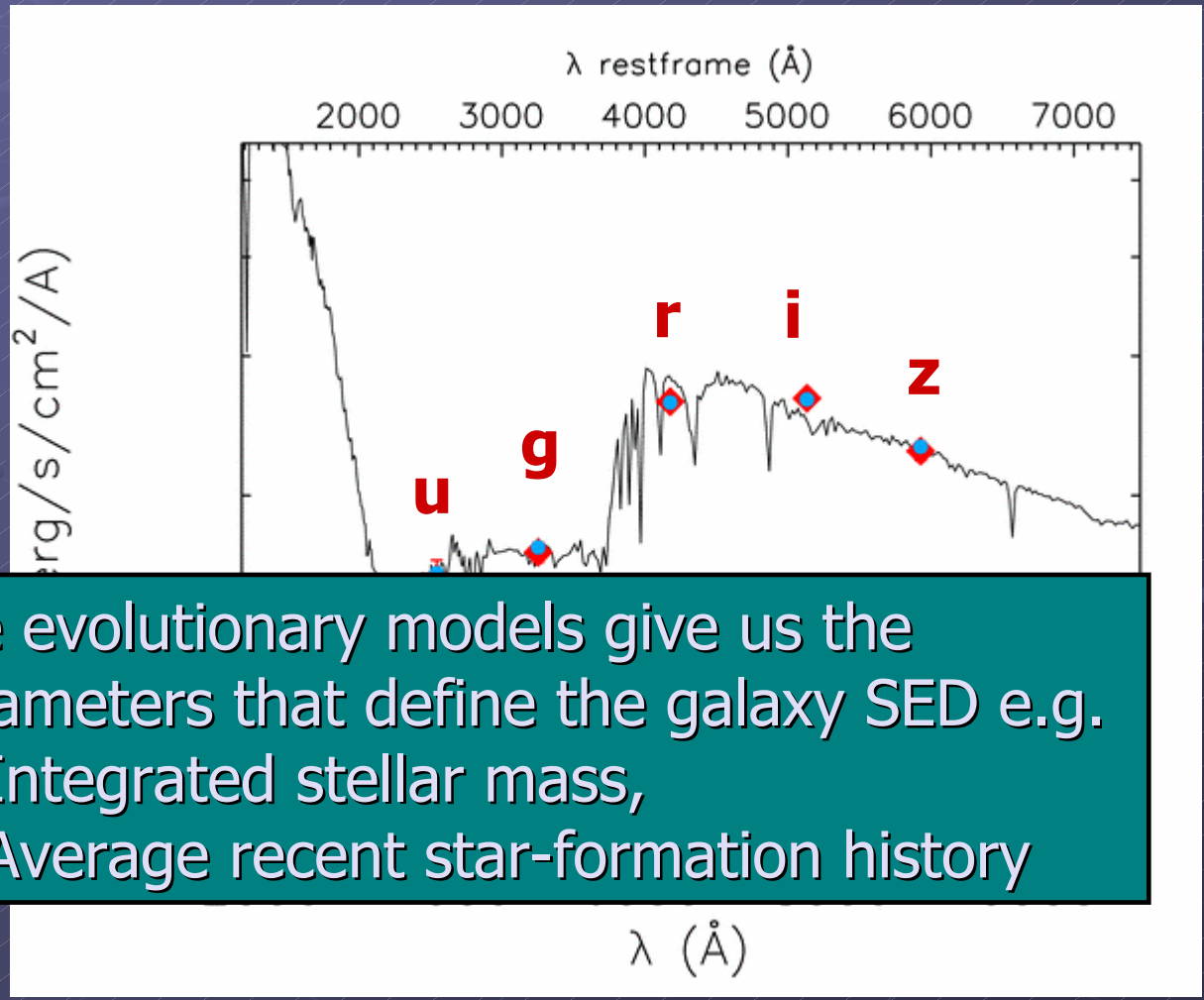
- Empirically model predicts:
  - SNIa rate depends linearly on host stellar mass
  - SNIa rate depends linearly on host current SFR
- SNLS provides ideal data to test this model thanks to:
  - Homogeneous SN dataset
  - Multi-wavelength host imaging

SNLS: Testing the model

- How do we get host mass and host SFR estimates?

<u>Spectral template fitting:</u>
PEGASE-2 photometric redshift code takes galaxy spectral templates, and fits them to observed magnitudes (ugriz fluxes)

As we know the redshift, we keep this fixed



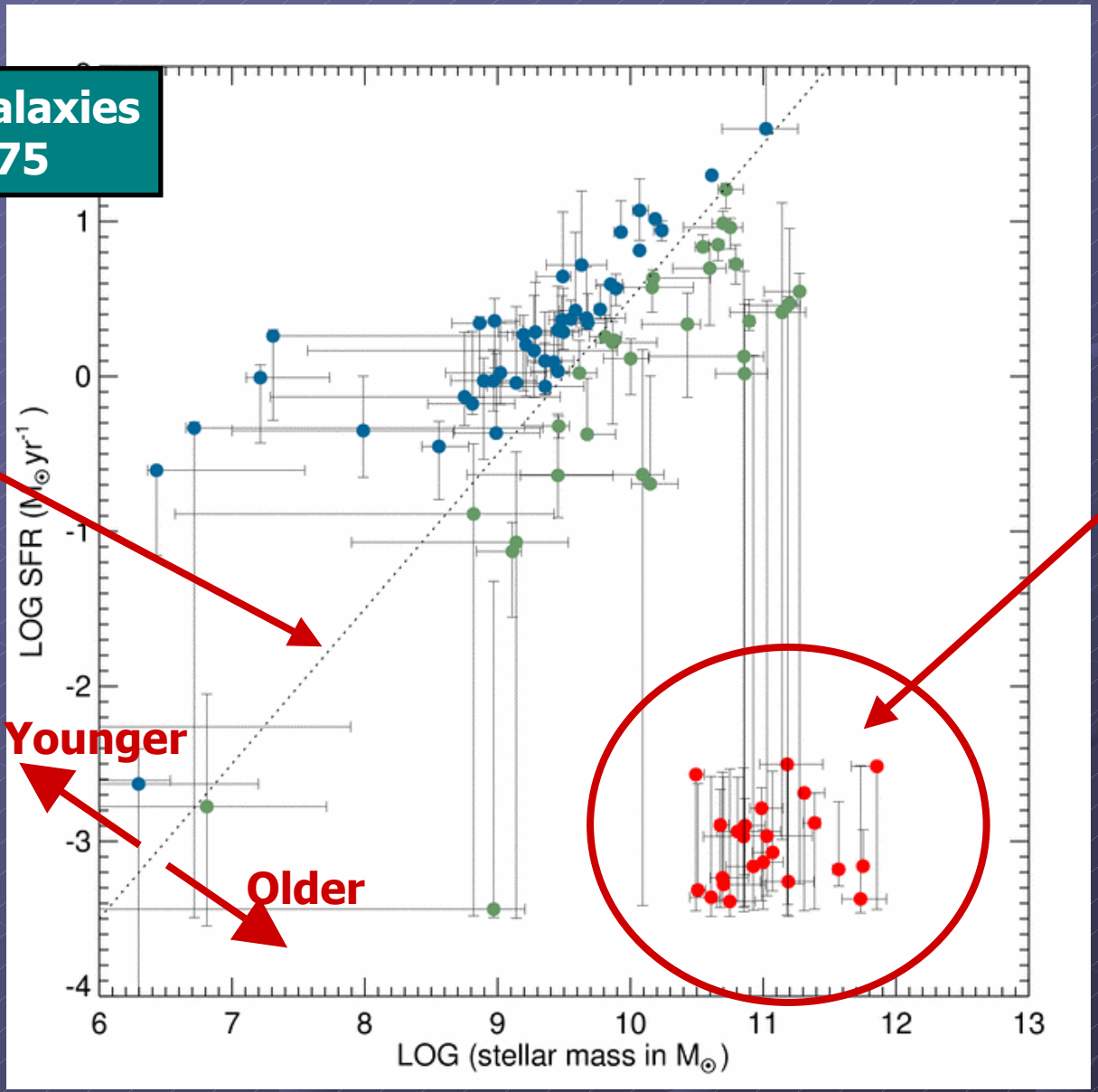
SNLS-03D1au z=0

The evolutionary models give us the parameters that define the galaxy SED e.g.
- Integrated stellar mass,
- Average recent star-formation history

SFR/Mass for the host galaxies

125 Host Galaxies at z<0.75

Line of constant specific SFR



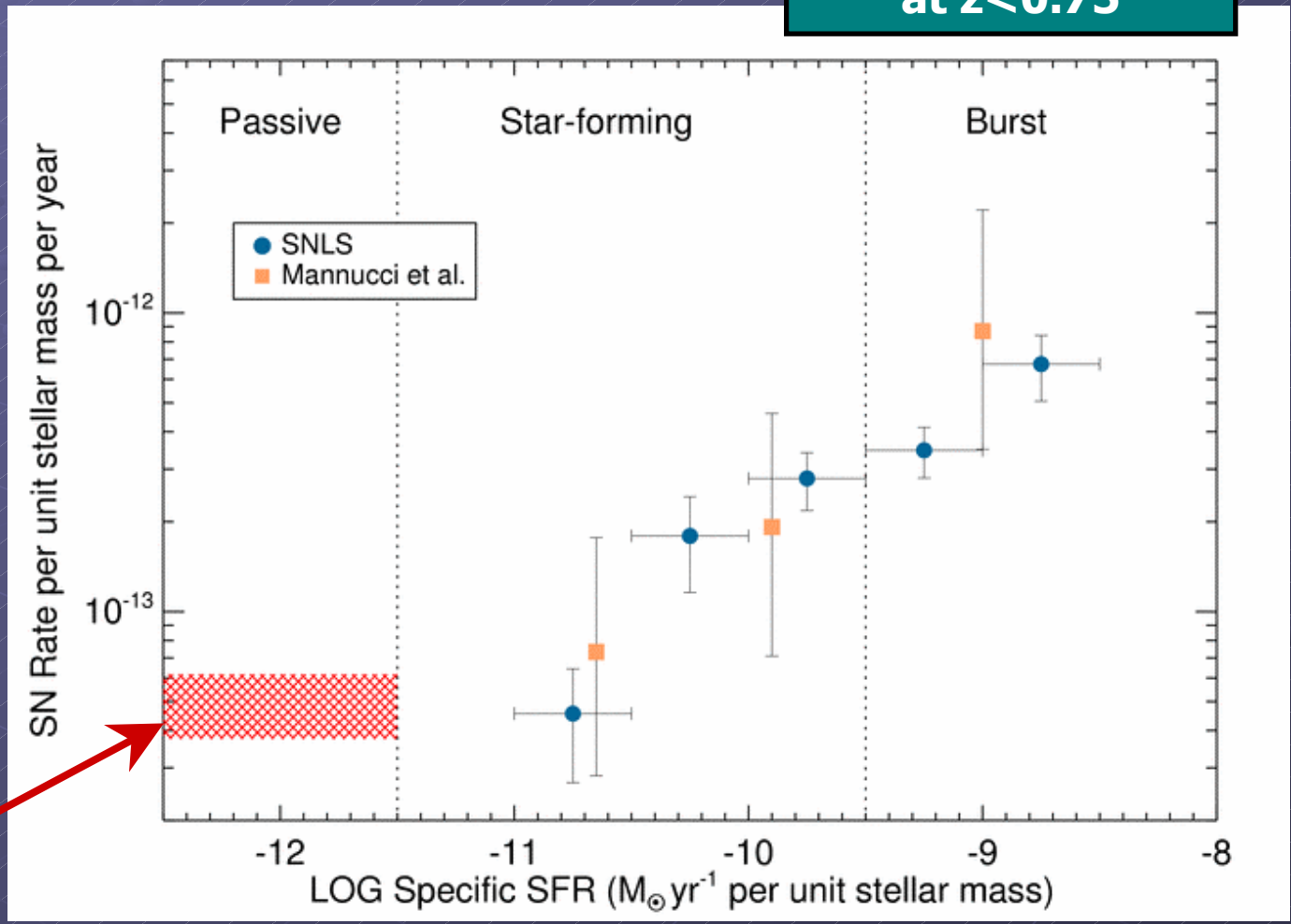
Passive galaxies have zero SFR

SNLS: SN rate as a function of sSFR

Use *specific star-formation rate* (SFR per unit mass) to classify the SNLS SNIa hosts

Per unit stellar mass, SNe are at least an order of magnitude more common in more vigorously star-forming galaxies

125 Host Galaxies at z<0.75



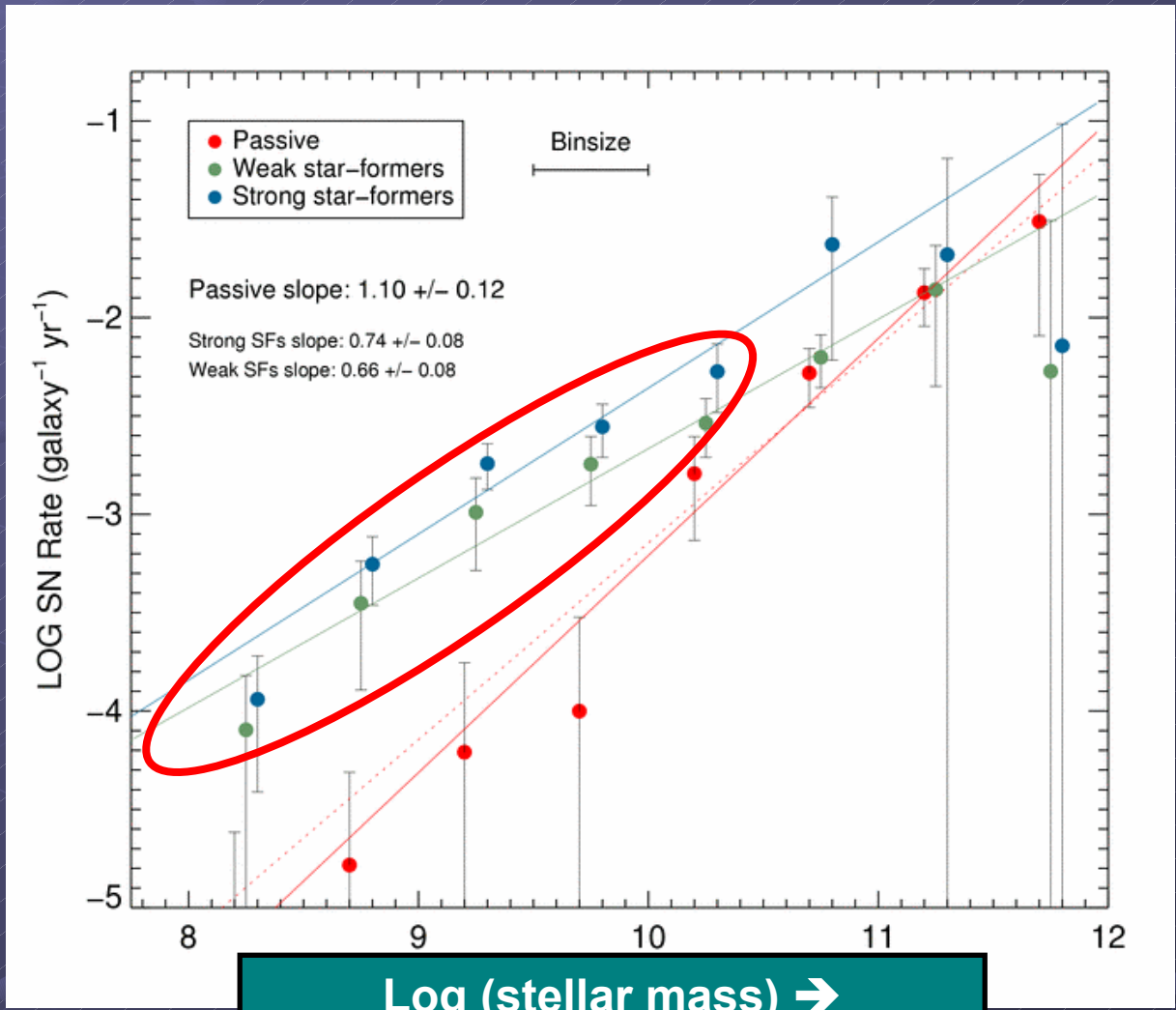
SNLS "passive" galaxies

Two component model – Mass

SNIa Rate by host mass

The SNIa rate is linearly proportional to host stellar mass in galaxies with no star-formation

Star-forming galaxies show an excess of SNe Ia at lower masses



Two component model – SFR

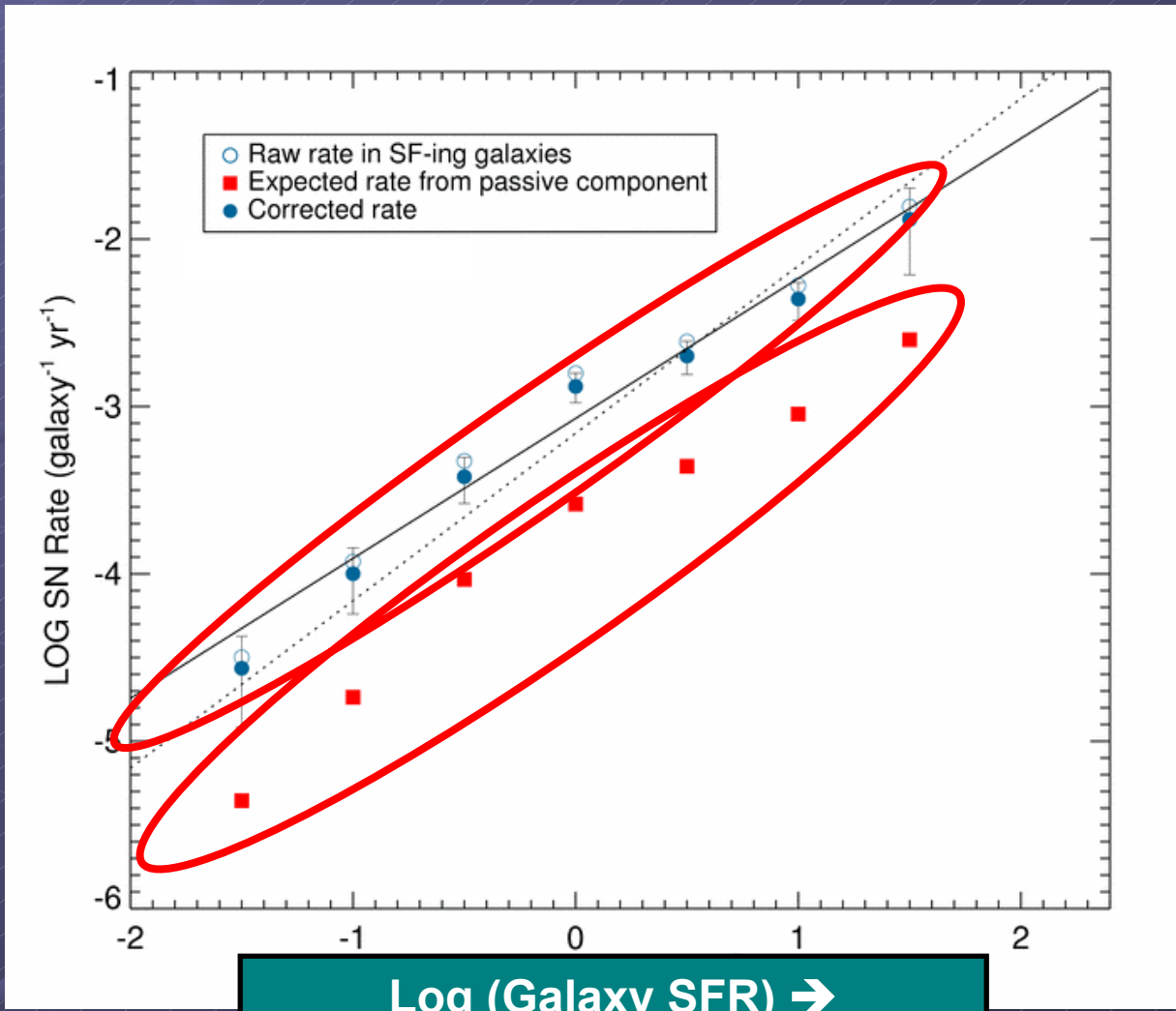
SNIa Rate by host SFR

Subtracting off the passive component in star-forming galaxies reveals that the SNIa rate is consistent with being linearly proportional to SFR

Fitting all galaxies simultaneously gives slopes of:

N_{mass}=1.02 ± 0.10

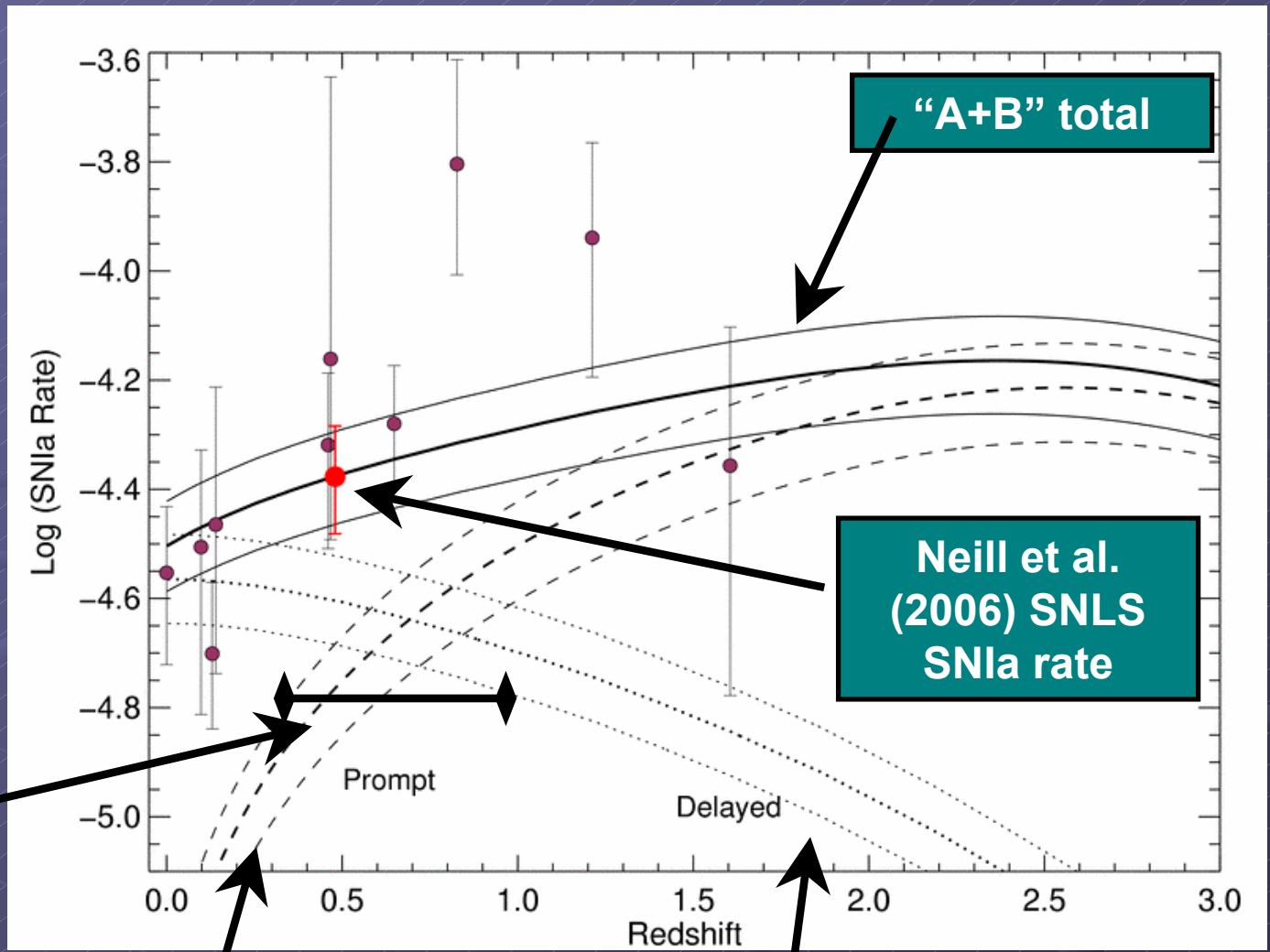
N_{SFR}=0.98 ± 0.11



Mix will evolve with redshift…

Relative mix evolves *strongly* with redshift

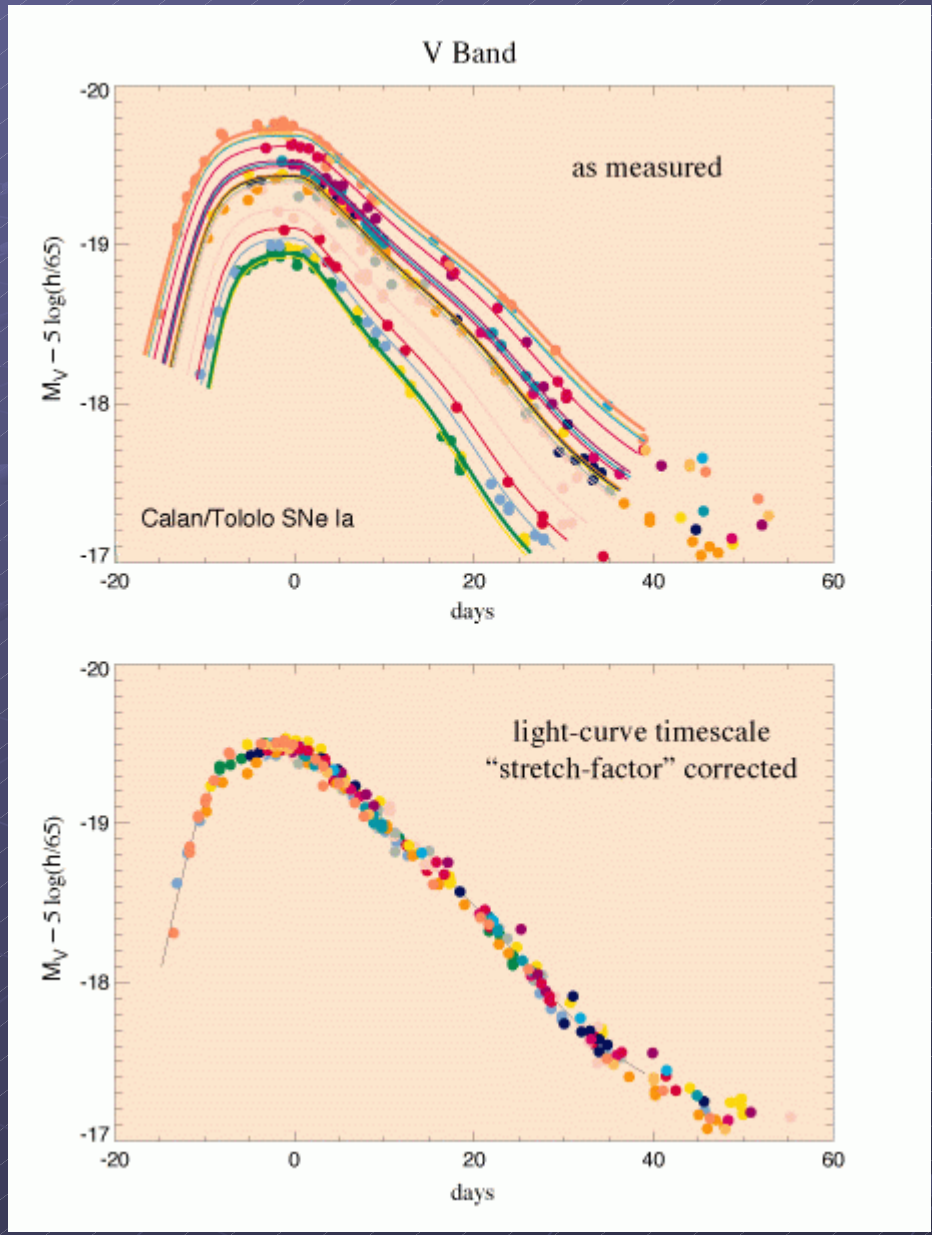
(Exact ratio depends on the details of the assumed star-formation history)



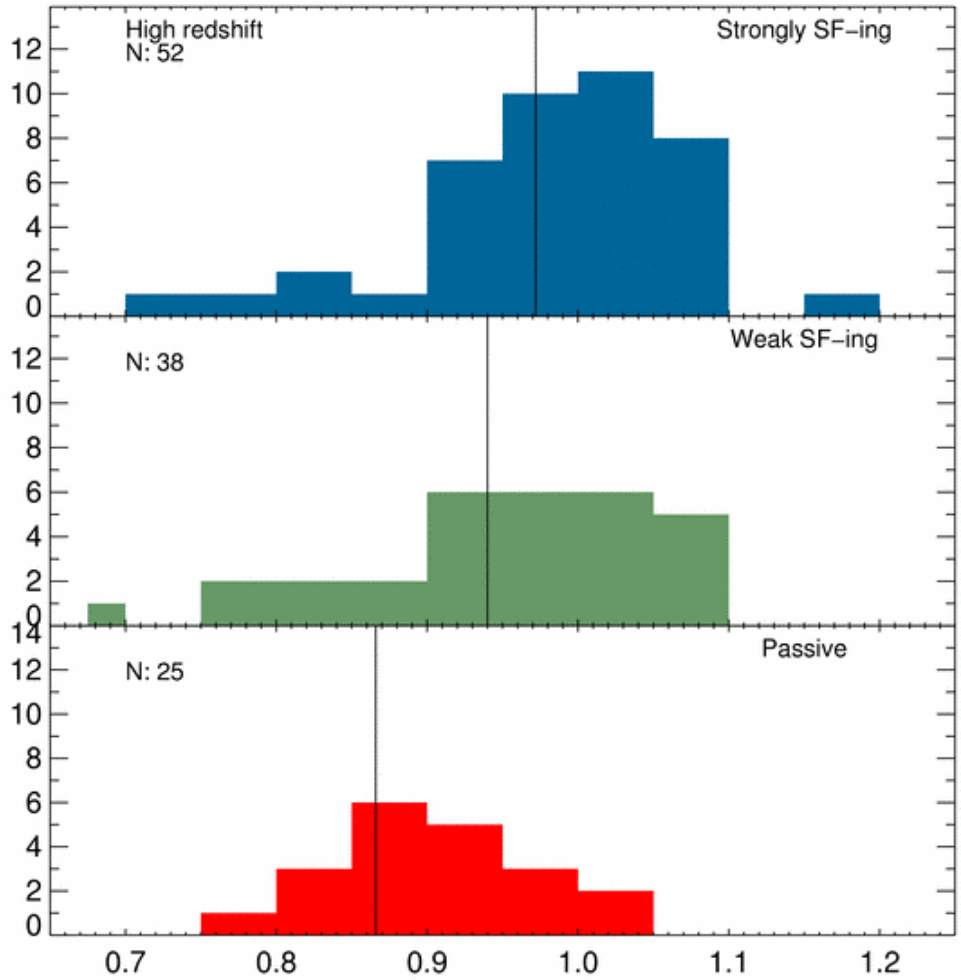
Light-curve width / host-type

- *Light-curve width* is a key parameter for standardizing SNe Ia as calibrateable candles
- We use the “stretch” technique (e.g. Perlmutter et al. 1997)

- Stretch is known to depend on environment locally:
  - e.g. Riess et al. (1999), Hamuy et al. (1995;2000)



Stretch/Environment



Stretch

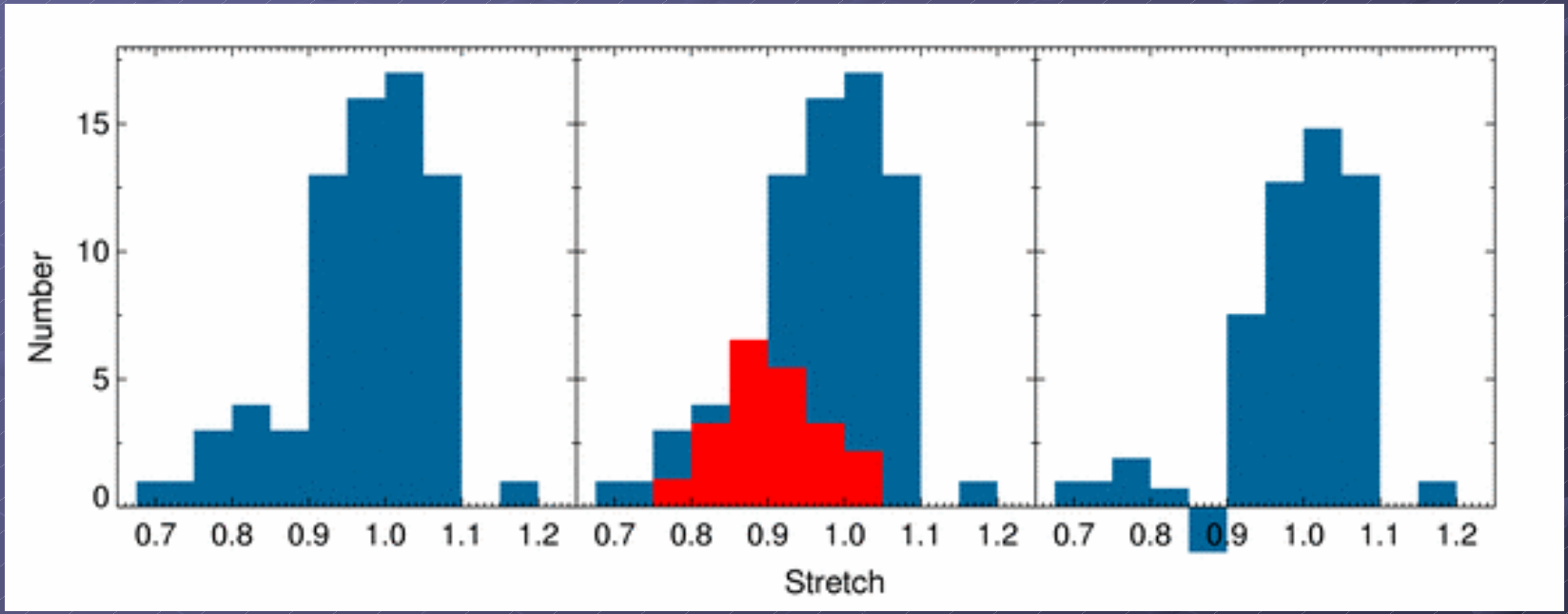
←Fainter SNe Brighter SNe →

Further evidence for A+B?

All star-forming galaxies

Star-forming galaxies plus “mass-scaled” passive

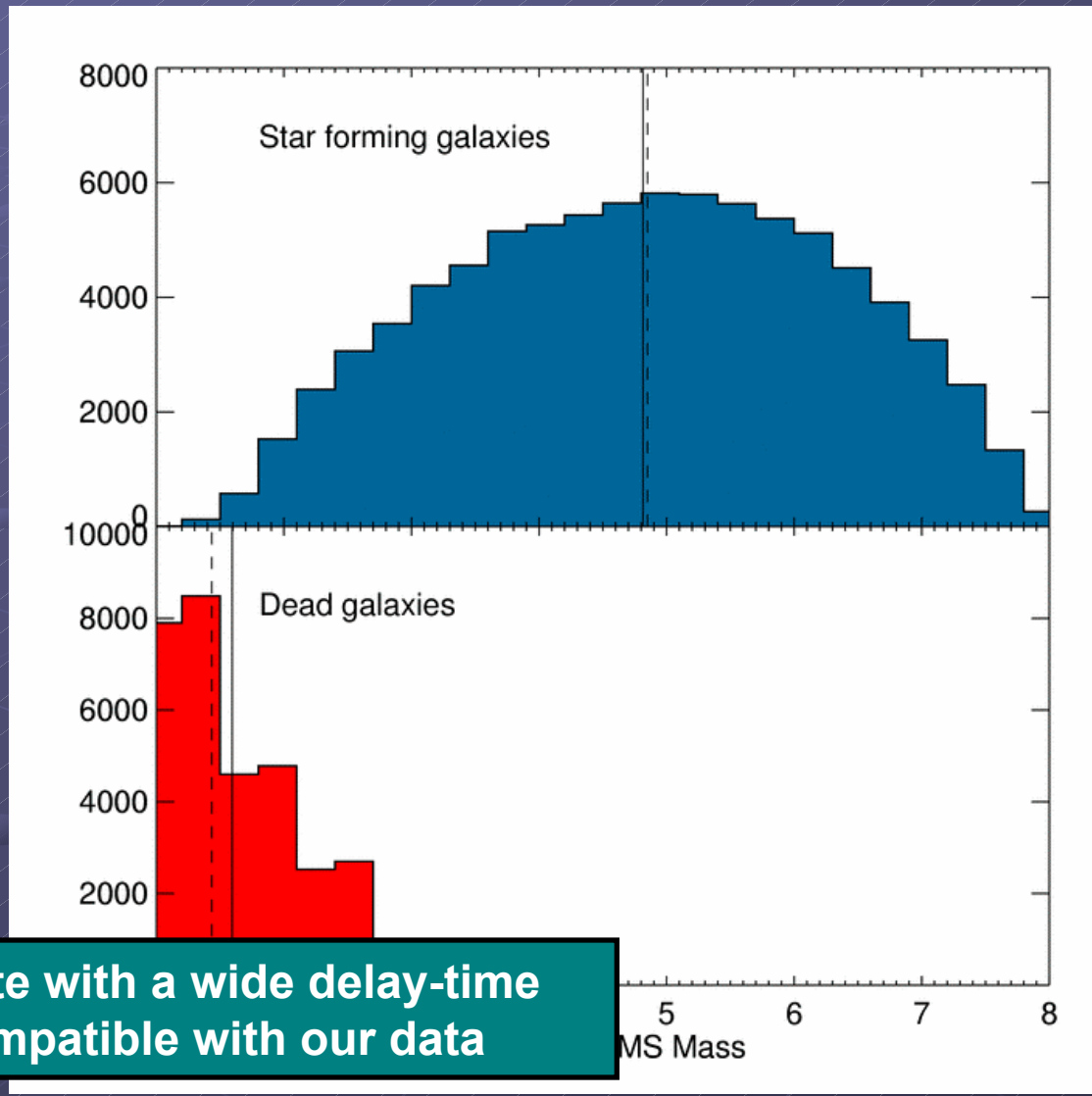
All star-forming galaxies MINUS passive



Progenitor constraints (Howell et al. 2006)

Can a single progenitor type still work?

- Assume *single degenerate* formalism of Greggio et al. (2005)
- For every host, we have estimates of the time since last star-formation event
- Monte-Carlo the distribution; generate secondary-mass distribution in every galaxy

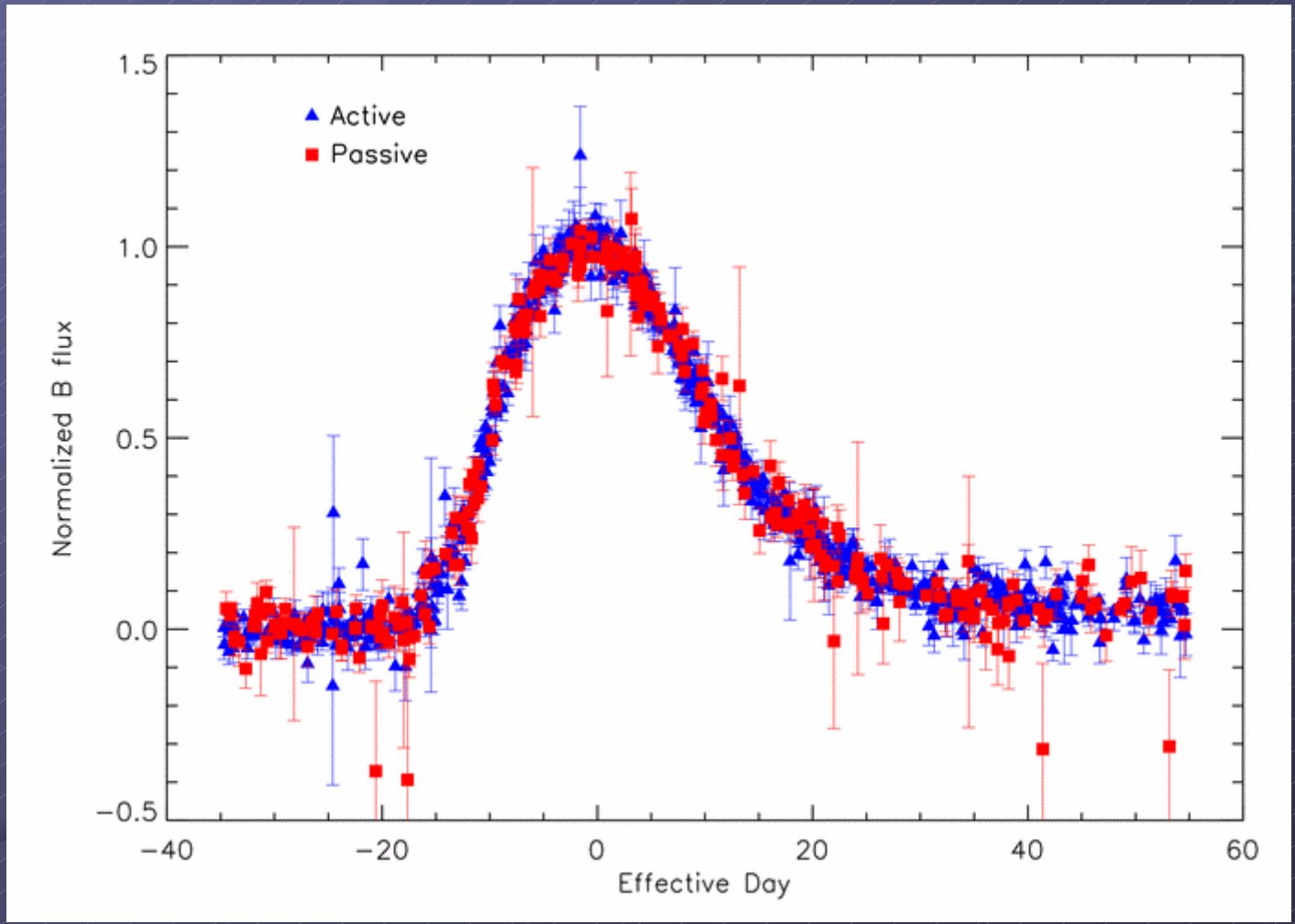


Single degenerate with a wide delay-time function is compatible with our data

Other environmental differences?

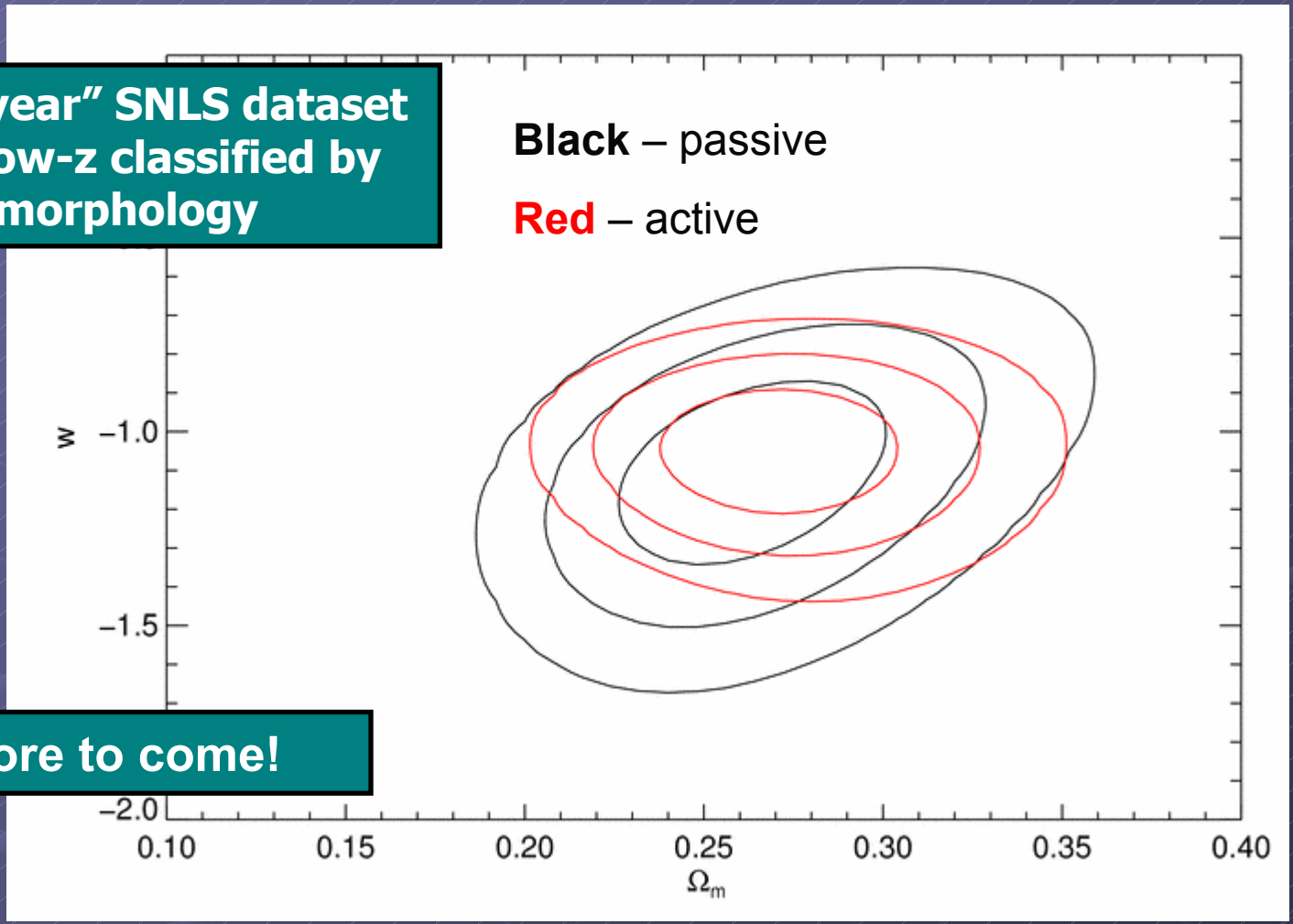
(Conley et al. 2006, in prep.)

No evidence for gross differences between light-curves in passive and active galaxies



Cosmological effects?

"First-year" SNLS dataset plus low-z classified by morphology



More to come!

Summary

- SNe Ia “know” about their environment – evidence for a very-wide range of delay-times, or two types of progenitor
- The light-curve width of SNe Ia depends on the environment in which the SN exploded
  - “Faster” SNe preferentially explode in passive galaxies
- No obvious UV spectral evolution to z=0.5; possible differences in UV properties as a function of environment?
- These environmental effects are not going to challenge the conclusion of an accelerating Universe
- However – systematic effects could easily affect the much more sensitive task of measuring “w” (and especially w’!)